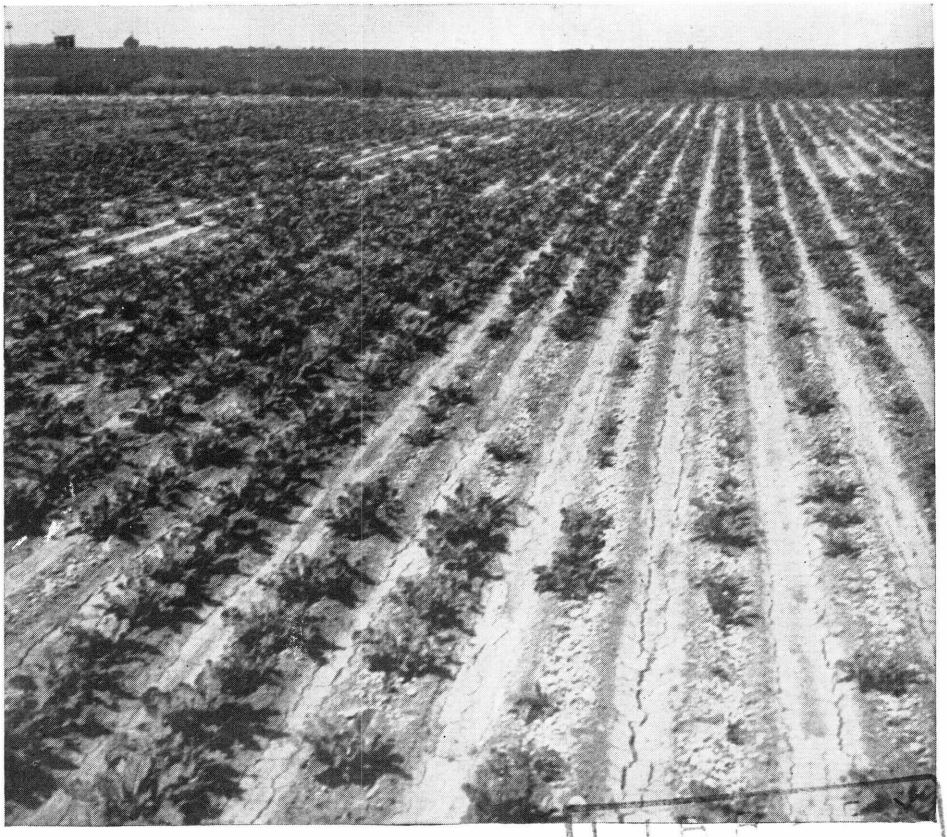
Control of the Sugar Beet Nematode



Farmers' Bulletin No. 2054
U. S. Department of Agriculture

THE SUGAR BEET NEMATODE is now established in almost every important sugar beet growing section of the United States. In many sections nematode control is one of the major problems of the beet-sugar industry, because beet acreage is limited by its presence. Other parts of the country, where the nematode has been found recently, must be prepared to cope with it and to prevent its spread to uninfested districts.

Control by crop rotation has been practiced successfully for many years, but this method has drastically reduced the sugar beet acreage in many districts. Because of this, the nematode has been an important factor in the closing of several beet-sugar factories.

Soil fumigation methods have been developed. With these growers can control nematodes effectively and can shorten the time between sugar beet crops. Fumigation, however, is expensive. Only the lighter sandy loams can be fumigated successfully at a cost the crop can bear. Usually fumigation is ineffective on the heavier clay loams.

This bulletin presents information on the value of certain crops that are generally used in rotations and gives instructions for soil fumigation. It discusses briefly the distribution, life history, and host plants of the nematode, and how it spreads.

This bulletin supersedes Farmers' Bulletin 1514, Control of Sugar-Beet Nematode by Crop Rotation.

Washington, D. C. Issued December 1952

Cover illustration.—A sugar beet field in which several small areas were infested with sugar beet nematode introduced by dump dirt.

CONTROL OF THE SUGAR BEET NEMATODE

By GERALD THORNE, *senior nematologist, Division of Nematology Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration*

Contents

DISTRIBUTION OF THE SUGAR BEET NEMATODE

THE SUGAR BEET NEMATODE[1] ranks as one of the major problems of the beet-sugar industry. This pest was first observed in the United States in a field near Lehi, Utah, about 1895. Since then areas known to be infested have increased in number and size until it is quite possible that no important beet-growing section will escape.

Since 1946 the sugar beet nematode has been reported for the first time from Kansas, Washington, and Michigan. Western States are in greater danger of infestation than the North Central States, because in western areas beets often are grown on the same land for several successive years—a practice that permits the nematode to become well established. Fortunately, continuous beet production is not common in the North Central States, and there is less danger that the sugar beet nematode will become a serious problem there.

Known infestations are as follows:[2]

CALIFORNIA.—The principal beet-growing districts in the neighborhood of the following places are generally infested: Betteravia, Chino, Oxnard, Santa Ana, and Spreckels. Numerous fields are also known to be infested near Alvarado, Clarksburg, Gonzales, King City, Lompoc, Manteca, Pleasanton, San Juan Bautista, Soledad, Tracy, and Woodland.

WASHINGTON.—A few farms near Toppenish are infested.

UTAH.—Counties generally infested are Cache, Davis, Salt Lake, Utah, and Weber. More limited infestations occur in Box Elder, Sanpete, and Sevier.

IDAHO.—Districts near Preston and Sugar City are generally infested. Numerous fields near Blackfoot, Bur-

[1] *Heterodera schachtii* Schmidt.

[2] The writer is indebted to officials of the sugar companies operating in the various States for much of the information on distribution of the sugar beet nematode in recent years.

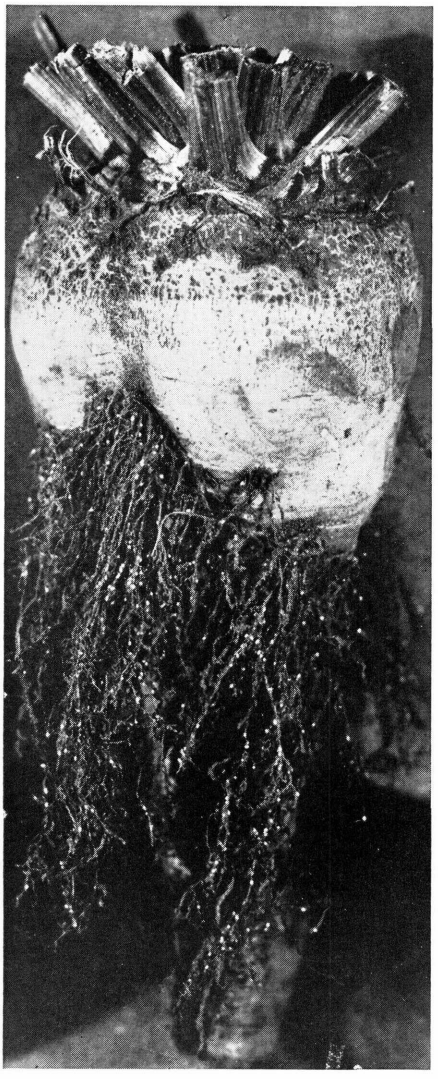


Figure 1.—Nematode-infected sugar beet. The small white bodies on the roots are female nematodes. (Actual size.)

ley, Idaho Falls, Rupert, and Shelley are infested, as well as three fields near Twin Falls.

WYOMING.—Several fields near Wheatland are infested.

MONTANA.—About 20 fields in the Billings district are infested.

COLORADO.—Numerous infested fields have been found in the neighborhood of the factories at Brighton, Brush, Eaton, Fort Collins, Fort Lupton, Fort Morgan, Greeley, Longmont, Loveland, Ovid, Sterling, and Windsor. The Arkansas River Valley has many infested fields between Pueblo and the Kansas-Colorado State line, the most seriously affected districts being those near Rocky Ford and Sugar City, and scattered fields near Avondale, Manzanola, and Vineland. On the western slope, about 20 fields near Delta and Grand Junction are infested.

NEBRASKA.—Numerous farms are infested in the districts around Bayard, Gering, Lyman, Minatare, Mitchell, and Scottsbluff.

KANSAS.—Only a few slightly infested fields have been observed between Dodge City and the Colorado-Kansas State line.

MICHIGAN.—About half a dozen infested fields have been found in the neighborhood of Bay City, Mount Clemens, and Saginaw, and one infested field has been found in Menominee County in the Upper Peninsula.

LIFE HISTORY

Nematodes observed in the field are females, which appear as small white bodies clinging to the beet root (fig. 1). These females contain from 100 to 600 eggs from which come slender worm-like larvae that average about one-sixtieth of an inch in length (fig. 2).

Figure 2.—Eggs and larvae of the sugar beet nematode. (Magnified about 80 times.)

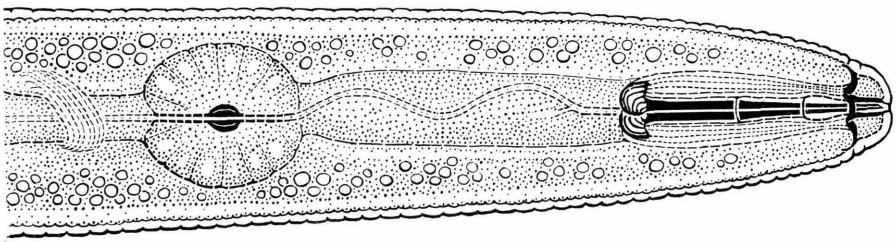


Figure 3.—Head of a larva of the sugar beet nematode, showing the spear with which it works its way into the beet root. (Magnified 1,400 times.)

The mouth of the larva is equipped with a strong nail-shaped organ known as a spear or stylet, with which it makes its way into the beet root. Here the larva feeds and passes through three molts before becoming an adult (fig. 3).

During the molting process the males develop into slender active eelworms, averaging about one-twentieth of an inch in length (fig. 4), which leave the roots and enter the soil in search of the females.

Development of the females is different from that of the males. After molting, the females are flask-shaped. As their size increases they break through the root tissues and remain attached by their heads. At this stage they are fertilized by the males and soon develop into lemon-shaped bodies about the size of a pin-head. A gelatinous fluid is excreted, which collects in a mass about the posterior end. Into this mass many of the females deposit some of their eggs, which soon hatch, the larvae finding their way into the soil or into the beet roots. The number of eggs deposited varies from a few to upward of a hundred, and since several generations occur each season there are soon enormous numbers capable of attacking the beets (fig. 5).

It is important to note that not all of the eggs produced by a female are deposited. The females die within a few weeks and change in color from white to dark brown, becoming what

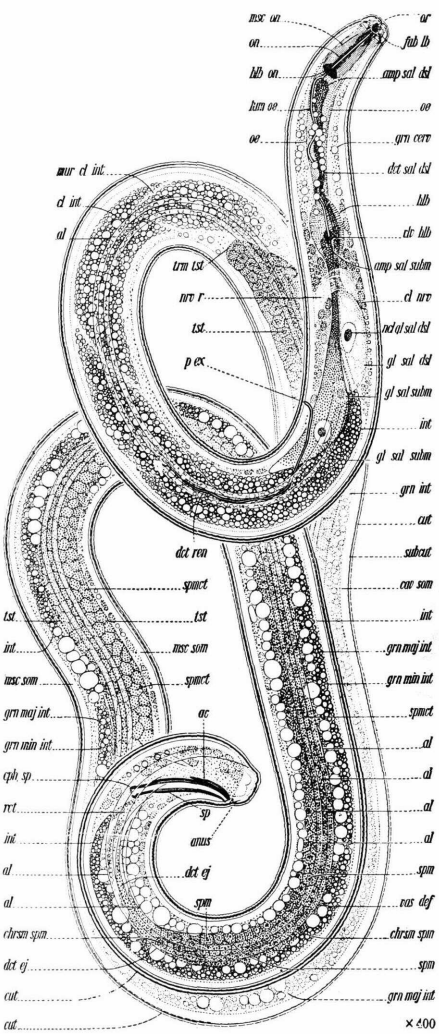


Figure 4.—Male sugar beet nematode. (Magnified 325 times. After Cobb.)

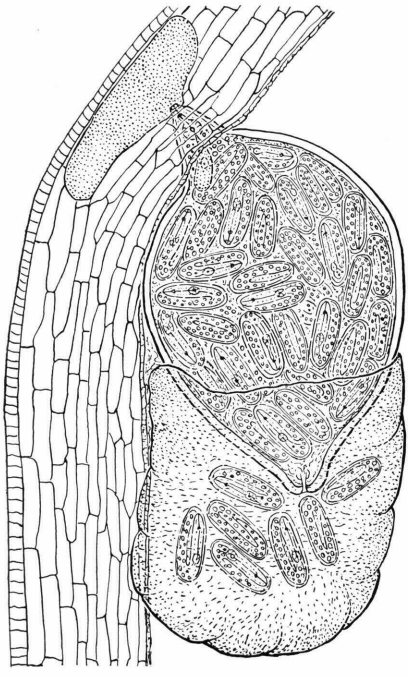


Figure 5.—Portion of a beet root, showing attached female nematode with gelatinous mass containing eggs. (Magnified 80 times.)

are commonly known as brown cysts. The eggs which have not been deposited remain within the cysts, and the larvae contained in these eggs remain dormant during winter months or through other adverse conditions. If sugar beets or other host plants are grown in the field most of the larvae hatch. However, if host plants are not present, only part of the larvae hatch each year, and these will die within a few months. Therefore the number of nematodes in the soil decreases with each passing year if no host plants are allowed to grow on the soil. Some, however, will remain unhatched and capable of attacking plants even after 5 or 6 years.

NEMATODE SYMPTOMS

Usually the first evidence of nematode injury observed in the field is the appearance of small areas that produce no beets or only a few undersized ones (fig. 6). Unless a considerable quantity of infested soil has been hauled into the field, these areas are not likely to be

Figure 6.—Typical small infested area that probably marks the spot where dump dirt containing nematodes was unloaded.

large enough to attract attention until 4 or 5 years after the trouble starts. By this time many nematodes will have been scattered to start small infestations in other parts of the field. On severely infested areas most of the young beets wilt and wither away just after thinning; often only a few remain, and these do not grow nearly as well as beets on clean soil nearby. Infested parts of the field are conspicuous on hot days, because the tops of the beets wilt much more readily than those of healthy plants.

Infected beets usually are small and stunted and have many more roots than normal beets, although many of the roots are brown and dead (fig. 7). Examination of the living roots will usually reveal the small, lemon-shaped white bodies of the female nematodes clinging to them. Later in the season the nematodes are found on the beet itself, and at this time it will probably be noticed that many of them are yellow or brown, indicating maturity and the development of the brown-cyst stage. These visible forms of the nematode are not able to move, and the observer should not confuse them with the sugar-beet root aphid,[3] which is a true insect several times as large as the nematode and which can be seen to move about slowly. These aphids are commonly found in dry spots in the field, where the beets they attack somewhat resemble those infected with nematodes.

Occasionally it is difficult to find nematodes on the beets even in severely infested fields. This condition is most usual in fields that are very dry. Even here, careful examination of the beets may reveal some of the brown cysts attached to the roots, but it is usually necessary to make a soil test.

Infestations can be detected even in the winter or when other crops have been planted. To do this, take samples of about one tablespoonful of soil each from numerous locations in a suspected area. Drop each sample into a glass of clean water. If there are a good many nematodes in the field, some of the brown cysts will immediately float to the surface, where they gather on the glass and appear as small, lemon-shaped, bright-brown bodies that are easily distinguished from the black weed seeds and other rubbish with which they may be associated. For one unfamiliar with their appearance, a small hand lens or magnifying glass will aid in making identifications.

Figure 7.—Typical nematode-infected sugar beet. A few white females can be seen attached to the roots.

Because of their weakened condition, beets infested with nematodes appear to be more susceptible to leaf spot and other diseases. For this reason such diseases are sometimes blamed

[3] *Pemphigus betae* Doane.

for inferior growth, when actually the primary cause is nematode injury to the roots. During early surveys of the Arkansas Valley in Colorado, the presence of small areas of leaf spot in the fields was often found to be associated with nematodes and, because of this leaf spot, the nematodes had been overlooked in previous years.

Other conditions that may produce an appearance similar to that of sugar beet nematode injury are alkali spots in the soil, attacks of the root-knot nematode,[4] garden (or white) centipedes,[5] excessive moisture, and dry spots. In fact, to be sure it is necessary to make an examination of the beet roots or of the soil and find the nematodes.

Newly infested districts follow a general pattern. Usually one or two fields are first observed in which nematodes have caused severe damage in areas covering several square rods, indicating that the pest probably has been present 4 years or more. By this time they have been spread to neighboring fields, and a careful survey of the locality will usually reveal several other small infestations. During succeeding years the nematodes spread to nearby fields, and after 20 or 30 years almost every farm in the neighborhood is infested.

When a grower detects the first few small infestations his first thought. almost always, is to eradicate the nematodes. Frequently a grower makes a real effort. However, as already explained, the areas first observed usually are only a small part of those actually infested in the locality and eradication measures are impractical because of these other undetected infestations.

[4] *Meloidogyne* spp.

[5] *Scutigerella immaculata* (Newp.).

SOURCES OF INFESTATION

The origin of sugar beet nematode infestations in the United States is not definitely known, as it is possible either that they may be native to the country or that they may have come from Europe in small clods of soil mixed with beet seed.[6] The brown cysts filled with eggs could easily have been carried in this manner, and, if these were planted with the seed, colonies of nematodes might have become established.

When once established in a field the nematodes are spread over it in many ways and will eventually reach all parts of the field: (1) Farm implements—especially cultivators, levelers, and harrows—drag particles of soil containing the nematodes from the infested areas and scatter them in other parts of the field; (2) irrigation water running over infested soil picks up cysts and larvae and deposits them along the furrows, where new colonies are soon established (fig. 8); (3) livestock crossing over a wet field may carry cysts in the mud on their feet and thus transfer the nematodes to other parts of the field or to other fields. Natural migration of the nematodes will carry them not more than a few feet in a season; therefore, the agencies listed above should be given first consideration in preventing spread.

Nematodes are carried from farm to farm by machinery, livestock, irrigation or drainage water, or any other agency that will transport the infested soil or the brown cysts from one place to another. Dump dirt doubtless has been chiefly responsible for the rapid increase of nematode infestations, because some of the soil from infected beets often collects on the dump screens at the sugar factories, is jarred loose by the load of beets that follows, and finds its way into the trucks of other farmers. Formerly this dump dirt was returned

[6] Charles Price, agronomist, of the Division of Sugar Plant Investigations, U. S. Department of Agriculture, once found living nematodes in lumps of soil picked from imported seed.

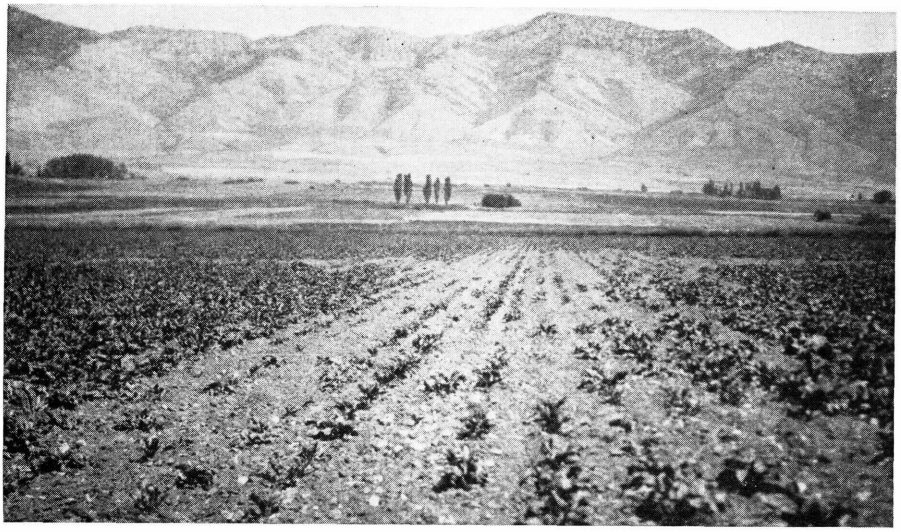


Figure 8.—Sugar beet field, showing distribution of nematodes up and down rows by irrigation water and by cultivation and across the field by leveling and harrowing.

to the field, but now the growers, realizing the danger of infesting their fields with nematodes, usually dispose of it in holes, swamps, or waste corners. Commercial truckers frequently haul beets for two or more growers at the same time and carry dump dirt from field to field and from farm to farm, often distributing nematodes, noxious weeds, and other pests. When trucks not belonging to the farm are used, special precautions should be taken to dispose of dump dirt, especially in those districts where only a few fields are known to be infested.

HOST PLANTS

To plan crop rotations for nematode control the grower needs knowledge of the host plants of the sugar beet nematode. Fortunately, the nematode grows and multiplies on only a few of the common crops and on a small number of weeds. This makes it possible to select a rotation that will effectively reduce the nematode population in almost any field.

The following lists of susceptible plants represent the results of hundreds of examinations of the various crops and weeds in all of the States except Kansas and Michigan in which the sugar beet nematode has been found.

Cultivated Crops: The only crops found infected in addition to beets are mangel-wurzel, table beet, cabbage, cauliflower, brussels sprouts, broccoli, rape, turnip, rutabaga, and radish. If any of these are planted on heavily infested soil, the plants often are attacked severely and the yield is reduced (fig. 9). At the same time such crops enable the nematodes to increase in number until it is impossible to produce a successful crop of sugar beets immediately following any one of them.

Weeds: Mustards (*Brassica* spp.), lambsquarters (*Chenopodium* spp.), nightshade (*Solanum nigrum*), and saltbush (*Atriplex* spp.) are common host plants of the sugar beet nematode and are an important factor in carrying the pest over in the field from year to year. Knotweed (*Polygonum minimum*), dock (*Rumex* spp.), redroot (*Amaranthus retroflexus*), and purslane (*Portulaca oleracea*) also are

Figure 9.—Cabbage field severely infested by sugar beet nematodes.

occasionally found infected. Unless a grower manages to kill these weeds by clean cultivation the nematodes may be able to live over. Surviving weeds can counteract much of the value of a crop rotation.

In Europe some crops, including peas, oats, and potatoes, and in Hawaii, sugarcane, which are not listed here as host plants, have been reported as susceptible to the sugar beet nematode. These reports have resulted from the fact that other species of nematodes, such as the golden nematode of potatoes [7] and the cereal nematode,[8] have been confused with the sugar beet nematode.

CONTROL METHODS

Prevention of Infestation

Serious infestation with the sugar beet nematode almost never occurs except in fields that have produced many crops of sugar beets with little or no rotation. Throughout the Western States it was not unusual for fields to have been planted with beets almost continuously for 10 to 25 years, thus making conditions ideal for the rapid increase of nematodes whenever a few happened to be introduced by dump dirt, irrigation water, or other agencies.

For growers, it is highly important to put an end to this dangerous custom. Even though a field gives no evidence that nematodes are working, it is wise to adopt a protective crop rotation in which sugar beets never grow in a field for more than 3 years in succession. Under a good long crop rotation, nematodes probably would not be able to multiply enough to cause serious damage.

Elimination of Small Infestations

Growers often find it practical to plant small infested areas with nonhost crops, leaving the rest of the field for sugar beets. Alfalfa and pasture

[7] *Heterodera rostochiensis* Wollenweber.
[8] *Heterodera avenae* (Mortensen, Rostrup & Kølpin Ravn) Filipjev.

mixtures are especially useful for this purpose, because there is less danger of spreading the infestation than if cultivated crops are planted. When small infested areas are used for alfalfa or pasture, the grower should allow 2 or 3 rods on each side of the infested area, as the nematodes are always distributed farther than is indicated by the severely injured beets. It is better to overplant than underplant in this form of protection against the spread of nematodes.

Crop Rotations

The number of sugar beet nematodes in the soil is reduced when no host plants are permitted to grow. If a field is planted to nonhost crops for a sufficient length of time, the number of nematodes in the soil will be reduced and a satisfactory crop of beets can be grown. But since some nematodes still remain even after 5 or 6 years it is practically impossible to eliminate them entirely. Crop rotations, therefore, should be planned not with the idea of eliminating the nematodes but of reducing their numbers, so that a satisfactory crop of beets can be grown as often as possible.

A desirable protective rotation is one that will give reasonable returns for labor and investment and at the same time increase, if possible, the productivity of the soil. In planning a rotation the following points must be considered: (1) Severity of the infestation, (2) crops adapted to the field, (3) market conditions, and (4) general fertility of the soil.

SEVERITY OF INFESTATION DETERMINES LENGTH OF ROTATION

Fields in which the injury is confined to a few small spots should be planted for 2 years with peas, beans, potatoes, tomatoes, corn, grains, white sweetclover, or other suitable nonhost crops, with legumes immediately preceding the sugar beets if possible. Such a short rotation will give a satisfactory yield of sugar beets once in each 3 years (fig. 10).

If the nematodes are destroying one-fourth or more of the beet crop, the field is likely to require a rotation of not less than 3, and preferably 4 or 5, years. For this long rotation alfalfa is most commonly used, but, if desired, the rotation may be made up of small grains, potatoes, peas, beans, tomatoes, and other suitable crops. A 4- or 5-year rotation usually reduces the infestation so that one profitable crop of beets can be grown. But under any system of rotation the grower must keep careful watch and if he finds serious nematode injury he will need to increase the interval between beet crops.

TWO SUCCESSIVE CROPS OF SUGAR BEETS ON INFESTED LAND INADVISABLE

When a grower gets a profitable yield of sugar beets on nematode-infested soil after a rotation, he may believe that another crop the following year should be nearly as successful. However, this is a mistake; the second crop almost invariably drops in yield until it is not more than one-fifth to one-third normal. The few nematodes that remain after the rotation increase to great numbers on the extensive root system of the first crop of beets, and thus severely injure the second crop (fig. 11).

CROPS TO GROW IN ROTATIONS

ALFALFA.—The sugar beet nematode does not attack alfalfa, and since alfalfa usually remains for three or more years after seeding it has become the most popular crop for long rotations. A good stand is essential, because in thin stands, weeds will grow in spaces between plants and on these the nematodes may live over from year to year. Examination of soil from alfalfa fields

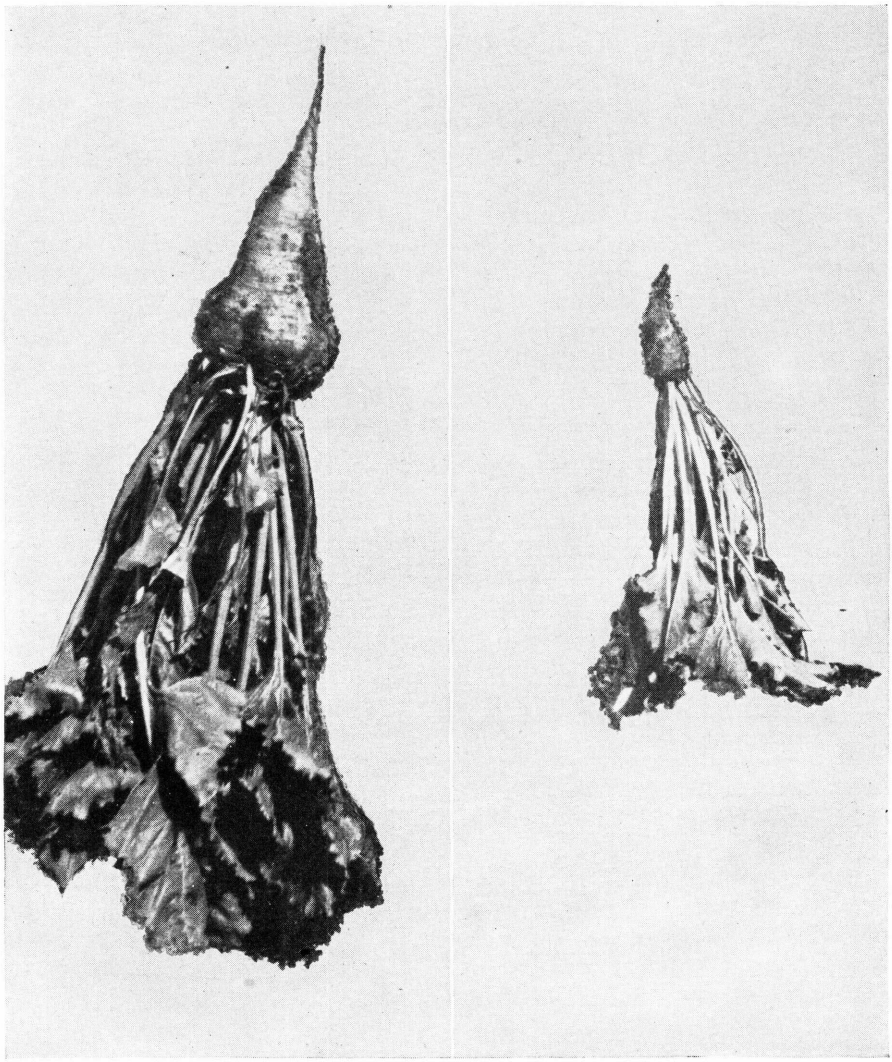


Figure 10.—Results of crop rotation on plants in a field in which many small areas were infested and the yield reduced to 12 tons of sugar beets per acre. Half of the field was planted first with potatoes and then with oats, while the remainder continued to be planted with beets. The beets shown were taken about 10 feet apart; the one on the left from the half rotated with potatoes and oats, that on the right from the part continuously in beets.

6 to 12 years old has shown that most of the nematodes remaining are in spaces between the alfalfa plants where weeds have grown. As alfalfa usually begins to thin out about the fourth or fifth year, it should not be allowed to remain longer, since the weeds that come in serve as host plants for the nematodes (fig. 12).

Usually it is not advisable to follow the alfalfa immediately with sugar beets, as many growers experience difficulty in obtaining a satisfactory seedbed. If the seedbed is not good, the young beets fail to get a good start in the spring and are more susceptible to the attacks of nematodes and to damping-off and other diseases. Most grow-

Figure 11.—Field showing result of two successive sugar beet crops on nematode-infested land. The part on the right was plowed up after 4 years of alfalfa and planted to potatoes. Beets were grown the next year and produced a satisfactory yield. The following year the left part of the field was plowed and produced a normal crop of beets, but the part on which a second crop was attempted was a failure.

ers prefer to follow alfalfa with potatoes, tomatoes, grain, or corn, which puts the soil in much better condition for the crop of beets that follows.

Alfalfa has commonly been classed as a "soil-building" crop, but in recent years this attitude has changed. Growers have come to realize the high phos-

Figure 12.—Harvesting a 26-ton crop of sugar beets from a field that had been in alfalfa 4 years, followed by wheat. Although many nematodes were present on almost every root, the beets are of good size. Foliage has been removed by a rotobeater and crowns mechanically topped.

phorus requirement of alfalfa. A 4-ton crop of alfalfa hay removes as much phosphorus from a field as do 12 tons of sugar beets, 40 bushels of wheat, and 150 bushels of potatoes combined. As a green-manure crop alfalfa once ranked high, but now it is rarely plowed under because it is worth much more as hay.

SWEETCLOVER. — This leguminous crop is widely used in certain sections as a hay, pasture, and green-manure crop. When a heavy crop is plowed under, the heat and gases of the decaying material kill large numbers of nematodes. Soil samples from such fields showed that the numbers killed ranged from 5 to 22 percent.

Sweetclover is not a host plant of the sugar beet nematode, and therefore it fits in well for short rotations on slightly or moderately infested fields. It is especially valuable on poorly drained soils or on soils where alfalfa does not thrive.

BEANS.—Beans are not hosts of the sugar beet nematode and are suitable to include in any rotation. One crop of beans on slightly infested fields usually will be followed by a good crop of beets. Placing one or two bean crops at the end of a 3- or 4-year rotation is a successful practice on severely infested land, especially in the beet- and bean-producing sections of California.

PEAS.—Peas of all kinds are excellent leguminous crops to fit into any rotation in sections where they are grown commercially. As they usually are harvested early in the season, an opportunity is given to plow the land and allow it to lie fallow for the rest of the year. This controls weeds and places the soil in good condition for sugar beets the following year.

POTATOES.—Potatoes are perhaps the most popular cultivated crop used in rotations. They may be used in any of the short rotations, but are especially suitable as a crop to precede sugar beets after the field has been in alfalfa for several years. After a crop of potatoes the soil is in excellent tilth, which is important in providing a good seedbed for sugar beets. Then, too, barnyard manure is often used with the potato crop and the residues benefit the beets.

WHEAT.—Wheat is not a host of the sugar beet nematode, but very often mustards, lambsquarters, and other host weeds of the nematode are found abundantly in this crop and thus enable many nematodes to live over. Wheat may be included in the longer rotations, especially as a nurse crop for alfalfa. If the field is clean of weeds, wheat may be used successfully, but liberal applications of barnyard manure or commercial nitrogenous fertilizers should usually be applied before sugar beets are planted.

BARLEY.—Barley is not a host of the sugar beet nematode and may be used in rotations in much the same way as wheat.

OATS.—Oats has been reported from Europe as a host of the sugar beet nematode, but the species observed was probably the cereal nematode previously mentioned. Therefore, oats may be used in rotations in the same manner as wheat.

CORN.—Corn is a good crop in any type of rotation, but if it is grown just before beets the coarse stubble often creates difficulties in drilling and cultivating.

TOMATOES.—Tomatoes can be used successfully in rotations, and, in those localities where they are grown commercially, they frequently precede sugar beets.

TRUCK OR GARDEN CROPS.—Because of the high soil fertility maintained in truck gardening, many of these crops are excellent in rotations on nematode-infested land. Onions, melons, celery, and lettuce are especially good. How-

ever, as previously emphasized, the following crops should never be planted on nematode-infested soil: Cabbage, cauliflower, brussels sprouts, broccoli, table beets, mangel-wurzels, turnips, rutabagas, and radishes. These are host plants of the sugar beet nematode and not only are often severely damaged but also permit the nematodes to reproduce and increase in number instead of decreasing, as is the case when non-host crops are grown.

Maintenance of Soil Fertility

The production of a successful beet crop depends upon how well the soil fertility is maintained, regardless of whether or not the soil is infested with nematodes. In some beet-growing sections the soil has been depleted and yields have been reduced to a point where it would be difficult to produce a profitable crop even if nematodes and other diseases were not present.

When nematodes are present, it is all the more important to maintain soil fertility. If beets do not make an immediate, thrifty growth from the beginning of the season, a comparatively small number of nematodes can check their growth until the yield may be seriously reduced.

During the early years of the beet-sugar industry barnyard manure was ordinarily the only fertilizer applied. In some areas, many farmers carried considerable livestock in proportion to their cultivated acreage, and thus were able to keep up an almost normal yield of beets and other crops.

Green manures are popular in certain localities, especially where there is not enough barnyard manure. Sweetclover and alfalfa are used most.

About 1935 growers began to use more commercial fertilizers on sugar beets. Phosphates were the first to be used in the Western States, where yields had dropped alarmingly in certain localities. Chemical tests later showed that these soils were seriously deficient in available phosphorus. Some soils, however, did not respond to phosphates as expected. In recent years further testing showed associated nitrogen deficiencies. Excellent yields resulted from application of nitrogenous fertilizers with the phosphates. Research on beet fertilizers is continuing.

Benefits of Early Planting

Planting as early as the season will permit is always advisable, especially when fields are infested with sugar beet nematodes. The young beets become established and are better prepared to withstand the attacks of nematodes, insects, and diseases that may appear later. The first nematodes usually become active at about the same time that beet growth begins in the spring. Even after a crop rotation there may be enough hold-over nematodes to check the growth of the young beets unless the plants are growing thriftily.

Beets Resistant to Sugar Beet Nematode

Occasionally growers and breeders have noticed sugar beets making superior growth on infested soil. These beets appear to be resistant to the sugar beet nematode. Many of them have been selected for seed increase and have been tested by growing them on infested fields. Invariably it turned out that these were plants of vigorous type that made a good growth in spite of the nematodes. Every selection proved highly susceptible. In fact, the spreading root systems of these extra vigorous plants actually enabled the nematodes to multiply more rapidly than usual.

Breeders have also investigated species of wild beets for resistance, but all have been found susceptible to some degree.

Figure 13.—This field was fumigated with 25 gallons per acre of dichloropropene mixture and produced 24.3 tons of sugar beets per acre, compared to 11.8 tons from an unfumigated part. Foliage has been removed from four rows with a rotobeater in preparation for mechanical harvesting.

Soil Fumigation

MATERIALS AND METHODS

Chemical treatment of soil to control nematodes, wireworms, and other soil-inhabiting pests is known as soil fumigation. The chemicals used for nematode control are called nematocides. For many years, it has been known that chloropicrin, carbon disulfide, and other chemicals kill sugar beet nematodes when injected into the soil. All these chemicals, however, were too expensive to be used on a field basis.

In 1943 it was discovered that dichloropropene mixtures[9] are good nematocides. In recent years several thousand acres of land infested with the sugar beet nematode have been fumigated successfully with commercial products containing these dichloropropenes. The average cost is about $40 an acre (1951), which still makes it an expensive process, but growers with limited acreage and soils in a high state of fertility have found that it pays. Best results have been obtained on light sandy soils having a moisture equivalent (moisture-holding capacity) of 20 percent or less (fig. 13). Heavy clay loams and peat soils have not responded so well to fumigation, and many attempts to control sugar beet nematodes on them have ended in failures.

An application of not less than 25 gallons to the acre must be made under average conditions. Reducing the amount of fumigant usually means a loss of about 1 ton of beets for each gallon less than 25. When properly applied, the fumigant kills a good share of nematodes down to a depth of 14 or 16 inches. Some nematodes near the

[9] Marketed under the trade names "D–D" and Nemafume.

surface are not killed, because the gas escapes and fails to build up a killing concentration.

Should a second crop be attempted without additional fumigation, it will be severely damaged (fig. 14). The fumigated experimental plots shown in figure 14, *A*, produced excellent beets, but huge populations of nematodes were built up on their spreading root

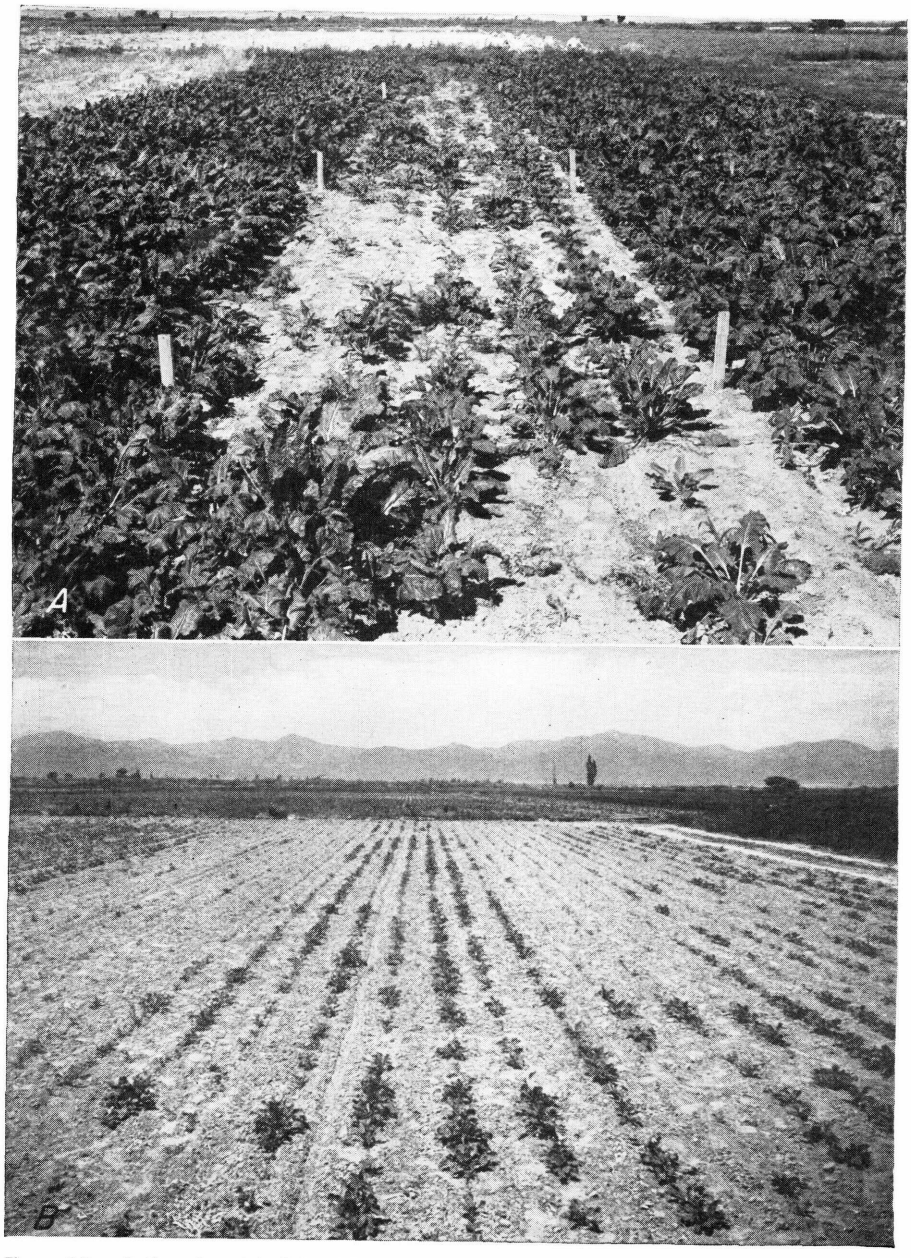


Figure 14.—*A*, Experimental plots with untreated check strip between those that were fumigated. *B*, The same plots planted the following year without additional fumigation.

Figure 15.—The third successive crop of sugar beets after fumigation every year; production about 20 tons per acre. The narrow unfumigated strip has few beets. (The following year this naturally fertile field was again fumigated and produced more than 25 tons per acre.)

systems, and the following year the beets in these plots were killed out almost completely (fig. 14, *B*).

Soil fumigants are poisonous to plants. Therefore, after fumigation, a field should not be planted until the gases have had time to diffuse and evaporate from the soil. If the weather is hot planting can follow within 7 or 8 days, but if cool and cloudy it is advisable to wait 2 weeks. In many localities this delay between fumigation and planting is a critical period because of loss of soil moisture. For this reason fall is the better time to fumigate. Fall fumigation permits planting just as early the following spring as the season permits. Fall fumigation is just as effective as that done in spring.

After one successful crop of sugar beets has been obtained by fumigation, it usually is a good practice to plant the field to potatoes, grain, tomatoes, peas, or some other annual crop before attempting a second fumigation. Many nematodes die the first year following sugar beets, and growing of a nonhost crop this one year enables the grower to take advantage of this natural reduction in population. Another important advantage is that it is usually practical to harvest one of these crops in time for a fall fumigation.

Soil fumigation is not a substitute for good farming and should not take the place of crop rotation. A very good practice is to give the nematode-infested field the usual crop rotation and grow one normal crop of sugar beets; then follow with a year of some nonhost crop, as mentioned above, fumigate in the fall, and produce another crop of beets the following year. After this the field should again be put through the usual long rotation. Fumigation allows an extra crop of beets in each rotation without too much of a drain on the soil fertility.

Fields with unusually high fertility will produce several beet crops in suc-

cession if fumigated every year, but this practice is not generally recommended, because eventually the nematode populations may be built up to a point where the usual 25-gallon application will not give a satisfactory control (fig. 15).

EQUIPMENT

Mechanical applicators of several types are available for soil fumigation, the larger commercial outfits consisting of tractor-drawn units that inject the fumigants under about 25 pounds' pressure through tubes welded to the

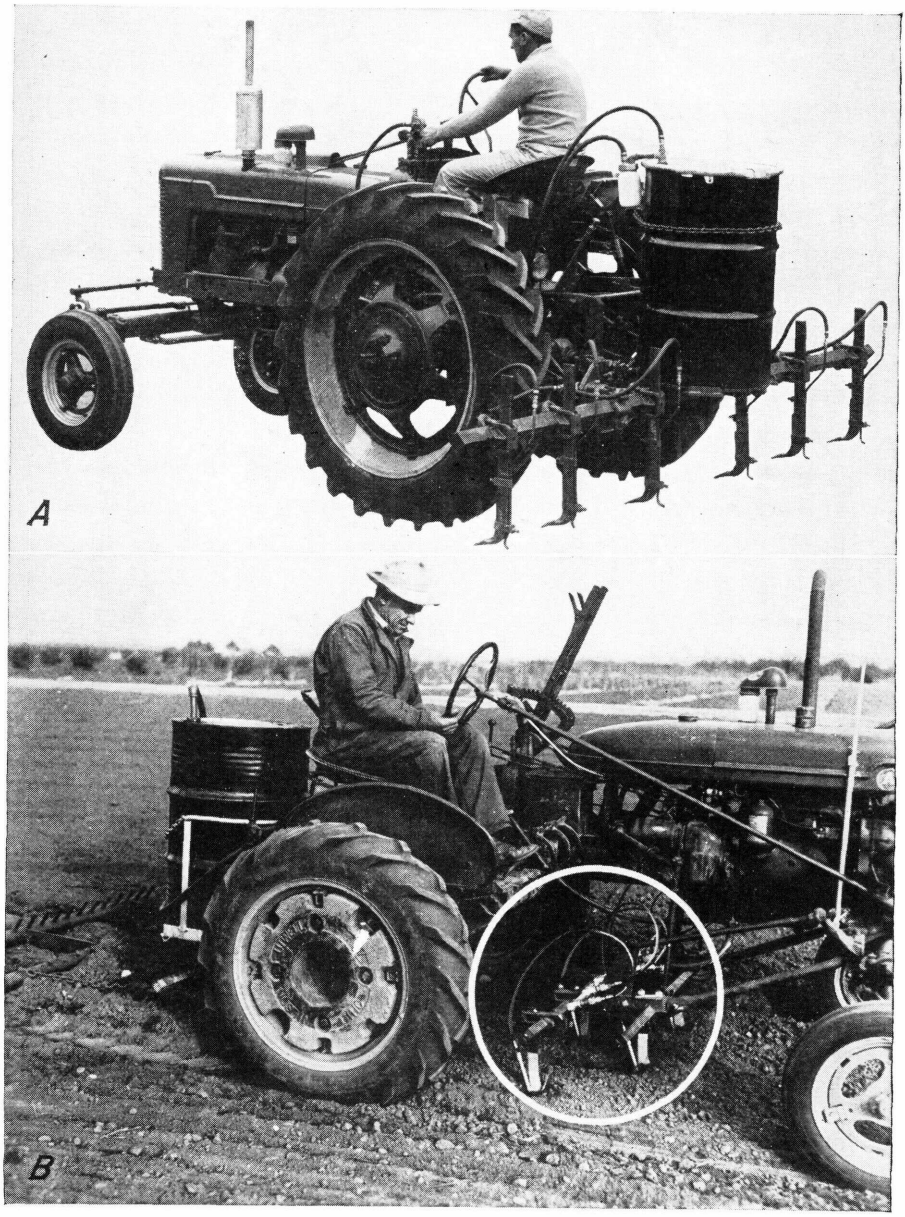


Figure 16.—Two large commercial-type applicators.

back of each chisel (fig. 16). Similar units have been built on the cultivator bars of tractors and are especially suitable for smaller land units. An inexpensive and popular unit is one that applies the fumigant on the bottom of the furrow when the land is plowed. This plow type is frequently used for fields on which an application of manure must be plowed under or on corn stubble where stalks and roots would interfere with the use of a chisel-type outfit.

INSTRUCTIONS

Soil fumigation is a technical process and must be done carefully. Observe the following instructions when fumigating fields for sugar beet nematode control:

1. Fumigate when soil moisture is the same as it is in a good seedbed. Dry, loose soil allows much of the gas to escape; excessive moisture prevents the gas from moving through the soil.

2. Use a thermometer and do not fumigate until the soil temperature at a depth of 6 inches is between 40° and 85° F.

3. Plow to the usual depth. Do not depend on disking, which rarely works the soil more than 4 or 5 inches deep, leaving a solid subsoil through which the gas cannot penetrate.

4. Fumigate soil that is in good planting condition—without large clods, straw, alfalfa roots, or coarse manure that will form pockets and permit fumigants to escape. Fields just broken from alfalfa are not in suitable condition for fumigation.

5. Apply dichloropropene soil fumigant at the rate of 25 gallons an acre, at a depth of 8 to 10 inches, with a chisel applicator, or at the usual plowing depth with a plow applicator.

6. Work the surface down firmly immediately after application with a harrow, leveler, drag, packer, roller, or other suitable equipment. This implement should follow immediately behind the applicator in order to confine the gas and get maximum benefits.

7. Delay planting 7 to 15 days after fumigation to avoid injury to seed or young plants from gas remaining in the soil. When possible, fumigate in the fall.

8. Be certain that soil fertility is high enough to insure returns for the investment in fumigation.

9. *Handle fumigants only in the open air and avoid breathing fumes. Be prepared immediately to wash fumigants from the hands with kerosene. Remove clothing or shoes in case they accidentally become wet with the chemicals; otherwise, severe burns may result. Should fumigants get into the eyes flush repeatedly with plenty of water.*

U. S. GOVERNMENT PRINTING OFFICE: 1952

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 10 cents